MI BPM 53 MHz Channel Transition Board Gains

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Bunch Structures and Beam Intensities

Define four bunch structures to consider:

1. Proton trains of 30 or more contiguous 53 MHz bunches (except for few bucket gap between Booster batches)
2. Proton 'short batches' of 5-9 contiguous 53 MHz bunches, e.g. for coalescing to fill Tevatron Collider
3. Antiprotons in 53MHz buckets for acceleration (four groups of ~five 53 MHz bunches each, groups separated by twenty-one 53 MHz cycles)
4. Single coalesced bunches of protons or antiprotons (i.e. bunches sufficiently isolated from any neighbors so that signal from one bunch dies out in BPM system before arrival of next bunch)

There are then two regimes to consider for each:

1. Specified measurement range intensities
2. Typical operating range intensities

	Structure	Spec. Min	Spec. Max	Typical
1a.	>30 bunches - protons	5E9/bunch	200E9/bunch	~100E9/bunch HEP
1b.	>30 bunches - protons	10E9/bunch	100E9/bunch	~ 11E9/bunch tune-up
2.	5-9 bunches - protons	30E9/bunch	100E9/bunch	~40-60E9/bunch 350E9 total
3.	53 MHz - antiprotons	5E9/bunch	10E9/bunch	8-15E9/bunch 300E9 total
4a.	Single bunch - protons	50E9	400E9	300E9
4b.	Single bunch - antiprotons	10E9	150E9	40-70E9/bunch

Bench Measurements

For fewer than ~10 contiguous bunches, the transition board peak output decreases with a decreasing number of bunches due to the rise time of the 53 MHz bandpass filter. Bench measurements of transition board relative peak output with different numbers of constant intensity bunch inputs produce results shown in Figure 1.

#Bunches	Peak mV output	Relative output
84	255	1
30	255	1
7	218	0.85
5	172	0.67
1	36	0.14

Figure 1. Transition board peak relative output for different numbers of contiguous test bunch signals.

Beam Measurements

Beam measurements were made with beam in each of the bunch structures. Data was taken through the EchoTek boards in raw data mode. The arbitrary gain reference in the discussion below is a setting of 0x0005 taken to represent unity gain. It is assumed that a setting of 0xFF05 corresponds to a gain of 48 db (linear gain of 250) and that the gain is proportional (in db) to the value of the upper byte in the gain setting. This gives about 1 db per 5.3 setting counts.

1a). 30 or more contiguous 53 MHz bunches:
8E12 protons in ~80 bunches (100E9/bunch) produces about 19,000 peak raw data counts in a short cable channel with transition board gain of 0x3305 (3.02 linear). This reduces to 64 counts peak signal per E9 per bunch at unity gain.

1b). 30 or more contiguous 53 MHz bunches
2.5E11 protons in ~30 bunches produced 23000 counts in a short cable with transition board gain of 0xA005 (32 linear). This reduces to 86 counts peak signal per E9 per bunch at unity gain; this is similar to the value of 64 as found in the high intensity measurement above.

2). 5-9 contiguous 53 MHz bunches:
3.5E11 protons in 7 bunches produced a scaled 83,000 counts in a short cable channel with transition board gain of 0xA005 (32 linear). This reduces to 53 counts peak signal per E9 per bunch at unity gain.

3). 53 MHz accelerating antiproton bunches:
2.5E11 antiprotons in their normal distribution of four groups of 53 MHz bunches produced about 20,000 counts peak in a short cable channel with transition board gain of 0xA005 (32 linear).

4a). Single coalesced proton bunches:
320E9 protons in a single coalesced bunch produced about 6000 counts peak in a short cable channel (<200ft.) with transition board gain setting of 0x3305 (3.02 linear).

4b). Single coalesced antiproton bunches:
45E9 pbars in a single coalesced bunch produced about 9000 counts peak in a short cable channel with a transition board gain setting of 0xA005 (32 linear).

Reasonable Gain Settings

This discussion also assumes that operating the system with signals at 1/3 full digitizer range at typical intensities is reasonable to provide good position measuring resolution while allowing suitable headroom for higher signals due to moderate intensity increase, off-center beams, and bunch length variations. Consideration here is given only for the gains of channels with short tunnel-to-service building cables. Note that all of this is 'fuzzy' at the level of nearly a factor of two due to bunch shapes, cable variations, splitters here and there, etc. In particular HP102 consistently yield signals that are a factor of two larger than nearby BPMs; this must be an "old style" wide aperture BPM that sums diagonal electrodes. [This BPM should have 6 db pads inserted in each of the two cables in the service building.]

There is an additional factor of four in dynamic range that must be accommodated in the system at 53 MHz for the range of MI BPM cable lengths. It is assumed that this will shortly be mitigated by the ability to set commensurately higher gains on channels with large cable attenuations. Note that this discussion pertains only to transition board gains for presenting suitably sized signals to the digitizers.

The corresponding 'sum signal' magnitude reported through the GrayChip and the EchoTek board is not considered here; that will be a function of GrayChip channel settings and beam signal duty factor.

1a). 30 or more contiguous 53 MHz bunches
Normal ~Full Batch High Intensity Operation:
Based on the beam measurements, for 1/3 full scale at typical intensity of 100E9/bunch, the gain should be 10677/19000 * 100/100 = 0.56 or -5 db relative to that of 3.02 used for the measurement for a total gain of 1.69 (4.56 db) or a setting of 0x1805.

1b). 30 or more contiguous 53 MHz bunches
Low Intensity 30 Bunch Tune-up Operation:
Based on the beam measurements, for 1/3 full scale at typical intensity of 3.5E11 (11E9/bunch) the gain should be 10677/23000 * 2.5/3.5 = 0.33 or -9.6 db relative to that of 32 used for the beam measurement for a total gain of 10.56 (20.5db) or a setting of 0x6D05.

2). 5-9 contiguous 53 MHz bunches:
Based on the beam measurements, for 1/3 full scale at typical intensity of 350E9 (65E9/bunch) the gain should be 10677/83000 * 350/350 = 0.13 or -17.8 db relative to that of 32 used for the beam measurement for a total gain of 4.16 (12.4 db) or a setting of 0x4205.

3). 53 MHz accelerating antiproton bunches:
Based on the beam measurements, for 1/3 full scale at typical intensity of 300E9 (8-12E9/bunch) the gain should be 10677/20000 * 250/300 = 0.45 or -7 db relative to that of 32 used for the beam measurement for a total gain of 14.4 (23.2 db) or a setting of 0x7C05.

4a). Single coalesced proton bunches:
Based on the beam measurements, for 1/3 full scale at typical intensity of 350E9 the gain should be 10677/6000 * 320/350 = 1.6 or +4 db relative to that of 3.02 used for the measurement for a total gain of unity or a setting of 4.8 (13.7 db) or a setting of 0x 4905.

4b). Single coalesced antiproton bunches:
Based on the beam measurements, for 1/3 full scale at typical intensity of 70E9 the gain should be 10677/9000 * 45/70 = .76 or -2.35 db relative to that of 32 used for the measurement for a total gain of unity or a setting of 24.3 (27.7 db) or a setting of 0x 9505.

This information is summarized graphically in Figure 2. The different bunch configurations are displayed on the horizontal axis. The vertical axis is gain scaled in decibels. Note that +6 db represents an amplitude gain factor of 2 or conversely a factor of two lower beam intensity. Short horizontal bars indicate gains required to provide 1/3 full range signals to BPM EchoTek digitizers for typical intensities of different bunch configurations. Colored, dashed horizontal lines indicate present LOW (9.6 db) and MEDIUM (30.1 db) gain setting values. Based on the data, assumptions, and logic presented here, the suggested settings for LOW, MEDIUM, and HIGH gain values for present typical operations are 5 db (0x1B05), 12 db (0x4005), and 21 db (0x7005) respectively. These are indicated by the lower edges of the colored bands in the figure; the upward extent of each band suggests the useful operating range for lower intensities at each gain selection.

The dashed vertical lines in Figure 2 represent the specified measurement range for each bunch configuration from the requirements document. The three suggested gain settings, with appropriate selection of LOW, MEDUIM or HIGH, can be seen to cover the full specified measurement range in the 53 MHz channel with two exceptions:

1. High intensity stacking and/or NuMI operation at intensities above 1E13 per batch (80-84 bunches). If this intensity is achieved the LOW gain setting value will need to be reduced.
2. Low intensity anti-proton operation at intensities more than a factor of two below the typical values assumed here. High resolution measurements in this range will require increasing the HIGH gain setting value.

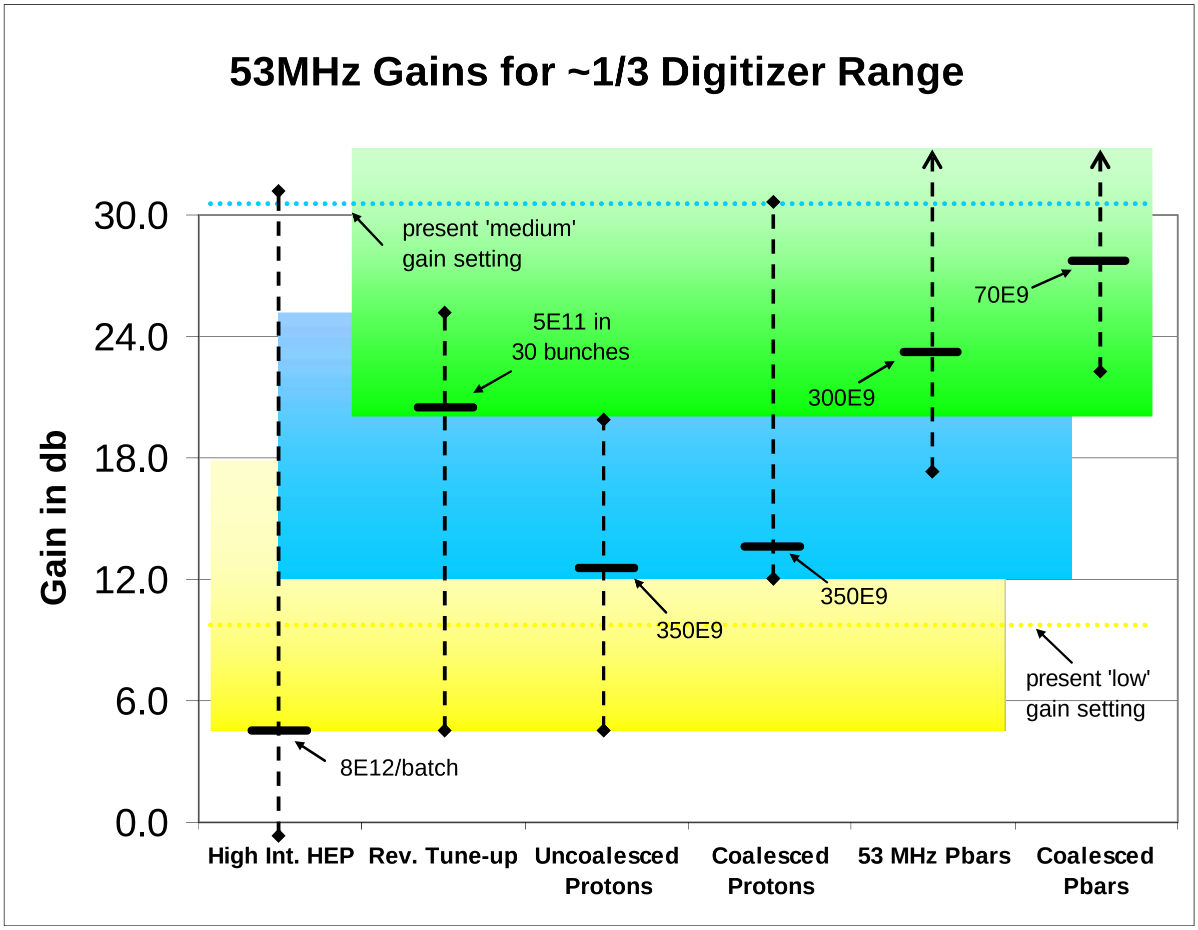

Figure 2. Horizontal bars indicate gains required to provide 1/3 full range signals to BPM EchoTek digitizers for typical intensities of different bunch configurations. Vertical lines represent specified range for each bunch configuration. Lower edge of colored bands represent suggested gain values for Low, Medium, and High gain selections for present typical operations. Dashed lines indicate present gain values for Low and Medium gain selections.